Dynamic electromagnetically induced absorption

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Abstract — Strong resonances in the absorption of circularly polarized light resonant with the $F_g = 2 \rightarrow F_e = 1$ component of the $^8\text{Rb} \ D_1$ transition are observed at zero magnetic field. An explanation based on a transient optical pumping process is presented.

In an ongoing study of the optical properties of atomic media with ground-state coherences, we have observed strong and narrow absorption resonances in circularly polarized light tuned to the $F_g = 2 \rightarrow F_e = 1$ component of the $^8\text{Rb} \ D_1$ transition using a magneto-optical Hanle-type arrangement (Figure 1). Using such an arrangement with linear-σ polarized light, laser-induced ground-state Zeeman coherence causes strong electromagnetically induced transparency resonances to be observed on this transition; however, the circular polarized light does not induce Zeeman coherence. Resonances of increased absorption have been observed previously using a similar magneto-optical scanning technique on the Cs $D_2$ line [1], but no physical interpretation of the effect was offered.

Fig. 1. Simplified experimental arrangement.

The Rb cell is heated gently and placed inside a solenoid to allow an external magnetic field to be applied along the laser propagation direction. The $\lambda/4$ plate allows control of the laser polarization.

An example of the strong absorption resonances using circularly polarized light is shown in Figure 2. To produce such a profile, the laser frequency is scanned over the Doppler width of the transition while the applied magnetic field is scanned about ten times faster, so that zeroes in the magnetic field occur several times in the profile. Because the strong absorption resonances occur at zero magnetic field and can have very narrow widths, they are strongly suggestive of ground-state Zeeman coherence-based electromagnetically induced absorption resonances [2], which are normally associated with transitions in which $F_g < F_e$.

The resonances are observed in cells containing buffer gas and in cells with anti-relaxation coated walls, but not in cells containing only Rb vapour. Their observation appears to require a long laser-atom interaction time. They are stronger in a broad beam than in a narrow beam. They can have very high contrast (> 50%).

We have explored the resonance in some detail and will present the results of this investigation. We have found that the amplitude of the resonance is very sensitive to proper cancellation of the background magnetic field. Indeed, it seems promising for magnetometry applications.

Furthermore, the width and shape of the resonance depend on the speed at which the magnetic field is scanned through zero, suggesting a dynamic process is responsible for their generation.

We have proposed an explanation of the resonances in terms of a transient optical pumping process: in the $F_g = 2 \rightarrow F_e = 1$ transition, σ+ circularly polarized light optically pumps a large number of atoms into the $m_f = +1$ and +2 states of the $F_g = 2$ level. This, combined with hyperfine optical pumping, reduces the absorption. As the magnetic field is scanned through zero and reverses direction, the laser polarization changes to σ− and the light is able to be absorbed by the optically pumped $m_f = +1$ and +2 atoms, producing a resonance of strong absorption.

This explanation is consistent with the behaviour of the observed resonances in the range of experimental conditions we have explored. For example, in the uncoated cell with no buffer gas, the optically pumped atoms move out of the laser beam and are replaced by unpumped atoms too quickly for significant population to build up in the optically pumped levels.

Fig. 2. Transmission profile showing strong absorption resonances at zero field on the $F_g = 2 \rightarrow F_e = 1$ component of the $^8\text{Rb} \ D_1$ transition using circularly polarized light.

REFERENCES